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Multiple Leadering of Coniferous Nursery Stock

D. P. Webb and K. H. Reese

A Joint Report of the Great Lakes Forest Research Centre and the Ontario Ministry of Natural Resources

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MULTIPLE LEADERING OF CONIFEROUS NURSERY STOCK

D.P. WEBB[1] AND K.H. REESE[2]

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FOREST RESEARCH CENTRE AND THE
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ABSTRACT

Loss of apical dominance resulting in seedlings with more than one leader, generally referred to as multiple leadering, has been formally under study by the Canada-Ontario Joint Forestry Research Committee working group on multiple leadering since 1978. This report summarizes the occurrence and possible causes of multiple leadering and recommends areas of future research, development of altered nursery practice to reduce the incidence of multiple leadering, and assessment of the longer-term effects of multiple leadering on seedling form in plantations.

RÉSUMÉ

La perte de la dominance apicale qui entraîne chez les semis la formation d'une pousse apicale multiple est étudiée depuis 1978 par un groupe de travail du Comité mixte de recherche forestière (Canada-Ontario). Ce rapport décrit brièvement l'apparition et les causes possibles de la formation de la pousse apicale multiple et formule des recommandations sur les recherches à effectuer, l'amélioration des méthodes en pépinières, afin de réduire la fréquence des pousses apicales multiples, et l'étude des effets à long terme de cette anomalie sur le port des semis dans les plantations.

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INTRODUCTION

Multiple leadering (ML) in conifer nursery stock has been formally under study by a Canada-Ontario Joint Forestry Research Committee (COJFRC) working group since 1978. This report is a summary of the information obtained up to the summer of 1982 on the occurrence and possible causes of ML, and includes recommendations for future research.

Multiple-leadered seedlings (seedlings with terminal shoots greater in length than 20% of main leader) are a problem because the culling rules for standard reforestation (STR) conifer stock require that seedlings acceptable for shipping have a dominant leader. The culling rule is based on the assumption that a transplanted single-leadered seedling (SL) produces a single-leadered tree in plantations. Studies on ML were initiated because the occurrence of multiple-leadered seedlings in seedbeds at some nurseries was becoming unacceptably high[3]. Although ML has been observed at various levels in all conifer stock, emphasis has been placed on spruce *(Picea* spp.) because it is common to most nurseries, is commercially important and has a consistently higher incidence of ML than other species.

The most obvious presence of ML stock is observed at shipping time when seedlings may be as much as 3 years old. It is now apparent, however, that seedlings may go into their first 1+0 winter with damaged terminals or damaged buds (Gross 1983). Further damage may occur over winter or in the early spring in subsequent years, and may result in the occurrence of ML at the time of shipping.

The first record of ML in Ontario nurseries is contained in field notes of the fall plant samples collected at Gogama in 1957. Krause[4] and Vaartaja and Dance (1964) carried out studies during the 1960s. The latter indicated that "cabbage heading" was not a pathological problem. Collembola population studies carried out at Swastika and Dryden in the early 1970s and the work by Marshall and Ilnytzky (1976) in western Canada led to the involvement of the Great Lakes Forest Research Centre in the mid-1970s and the formation of a COJFRC working group in 1978. The University of Guelph was contracted in 1980 to assist in the field studies under the direction of the working group.

Possible Causes of Multiple Leadering

From the surveys undertaken at Ontario nurseries (Gross 1983; see also footnotes 4, 5, 6, 7 and 8) it is recognized that damage to terminal meristems

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[3] Sippell, W.J. and Gross, H.L. 1977. Seedling losses in provincial nurseries caused by multiple-leadering and recommended courses of investigative action (unpubl. rep. to COJFRC).

[4] Krause, H.H. 1963. Univ. New Brunswick, Fac. For., Fredericton, N.B. (pers. comm. to Forest Insect and Disease Survey Unit, Great Lakes Forest Research Centre).

[5] Hofstra, G. and Lumis, G. 1980. Univ. Guelph, Guelph, Ont. (pers. comm. to COJFRC working group).

[6] Hofstra, G. and Lumis, G. 1981. Univ. Guelph, Guelph, Ont. (pers. comm. to COJFRC working group).

[7] Sippell, W.J. and Gross, H.L. 1976. Great Lakes Forest Research Centre, Sault Ste. Marie, Ont. (unpubl. rep. to COJFRC).

[8] Sippell, W.J. and Gross, H.L. 1977. Great Lakes Forest Research Centre, Sault Ste. Marie, Ont. (unpubl. rep. to COJFRC).

generally results in loss of apical dominance and in ML, depending on intensity of damage.

Terminal injury has been associated with several biotic and abiotic agents. Although injuries resulting from insects and diseases have not been completely ruled out, it would appear that they are not primary causal agents of ML (Vaartaja et al. 1964, Gross 1983, see also footnotes 9 and 10). Similarly, assessment of factors such as fertilization burn, nutrient disorder, micronutrient deficiency, excessive drying conditions, herbicide soil residues, soil toxins and mycoplasmas based on experimentation carried out generally over a single time frame have not led to the identification of a factor or factors responsible for repeated and consistent damage associated with the observed incidence of ML (Thomas 1958, Rudolf 1964, Gross 1983; see also footnotes 10, 11, 12, 13 and 14). However, it is recognized that some of these potential causal agents are responsible for low-level background occurrence of ML (generally under 5%) observed from year to year.

Two general subdivisions in observed damage stand out:

1) Damage to terminal meristems during the period of bud formation and needle primordia initiation that has been found generally in provincial nurseries (much of the damage occurring at Midhurst is of this type).

2) Damage to terminal meristems as a result of frost damage or over-winter desiccation of buds that is generally restricted to the northern nurseries (much of the damage occurring at Swastika nursery is of this type).

Type 1 Damage

It has been observed that a high incidence of terminal injury occurs late in the growing season in early September when seedlings are in a growth phase, from the time when terminal buds are being initiated to the onset of dormancy. This suggests that something is markedly interfering with the normal processes of bud formation and needle primordia initiation. During this period damage is not outwardly apparent. Dissection of terminal buds that appear normal reveals abnormalities ranging from extremely small apical primordia, total absence of apical primordia, multiple apical primordia initiated at the terminal bud (Reese syndrome), to chlorosis of otherwise normal primordial shoots. Most seedlings

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[9] Syme, P.D. 1978. Great Lakes Forest Research Centre, Sault Ste. Marie, Ont. (unpubl. rep.).

[10] Hofstra, G., McLeod, C., Keefer, D. and Ensing, J. 1982. Univ. Guelph, Guelph, Ont. (unpubl. rep. to Ont. Min. Nat. Resour. Nurserymen's Meeting).

[11] Webb, D.P. 1981. Great Lakes Forest Research Centre, Sault Ste. Marie, Ont. (unpubl. rep.).

[12] Sadreika, V. 1981. Ont. Min. Nat. Resour., For. Resour. Br., Toronto, Ont. (pers. comm. with D.P. Webb, Great Lakes Forest Research Centre) (unpubl. rep.)

[13] Smith, W. 1979. Ont. Min. Nat. Resour., Swastika For. Nursery, Swastika, Ont. unpubl. rep.)

[14] Kong, K.T. and Day, R.J. 1974. Lakehead Univ. Fac. For., Thunder Bay, Ont. (unpubl. rep.).

are single-leadered throughout their first year of growth (Gross 1983; see also footnote 10) but many frequently have terminal injuries that are subsequently expressed in multiple-leadered growth. Results obtained by Webb[11] suggest that herbicide residues observed in soil and buds may be responsible for abnormal bud development. Residue levels were found to be correlated with the occurrence of ML, although no cause and effect relationship was found[13]. Similar results obtained by Kong and Day[14] indicated that applications of herbicide to white spruce *(Picea glauca* [Moench] Voss) were related to abnormal root:shoot ratios, susceptibility to terminal shoot damage and increased ML. Results indicate that herbicides may be involved in ML of spruce nursery stock, but the effect is not a simple cause-effect relationship; other factors are undoubtedly involved. The numerous potential causal agents referred to earlier have been examined on a "yes-no" basis over discrete and limited time periods. It would appear that the possible causal agent and, hence, any differences between affected and normal seedlings may have long disappeared at time of measurement. There is a need to examine potential causal agents over the full phenology of seedling development if we are going to detect significant changes. Similarly, the work to date indicates a general lack of experimentation to determine the role of microclimate in ML especially as a variable associated with other causal agents, i.e., herbicides and nitrogen fertilization. It has been demonstrated[10,15] that seedlings potted in nursery soil and grown in the greenhouse or outside have a very low incidence of ML. Similarly, in container stock in which herbicides are not employed to any great extent and environment is controlled, ML is essentially absent.

Type 2 Damage

Multiple leadering has also been associated with frost damage as found at Swastika Nursery and other northern nurseries. It has been observed[11,16] that induction of bud "dormancy" in nursery-grown seedlings occurs much later than in naturally grown stock. Considerable shoot elongation occurs in nursery grown spruce in late August and early September and this appears to be promoted by nursery cultural practice. These practices increase the risk of terminal injury and subsequent loss of apical dominance. Levels of nitrogen fertilization were correlated with ML in tests by Hofstra et al.[10] Results of growth chamber experiments (Colombo et al. 1982) indicate that cold hardiness is directly correlated with shoot growth cessation and terminal bud initiation. Altered nursery cultural practices employing early cut-off dates for supplemental nitrogen fertilization and herbicide application resulted in decreased terminal injury and subsequent decrease in ML[11]. These results indicate that the increased ML resulting from frost damage may be reduced by altered nursery cultural practices.

EFFECTS OF MULTIPLE LEADERING ON NURSERY PRODUCTION

Damage typical of ML was first recognized at Gogama in 1957 and since then reports of high seedling cull are on record at Gogama (1961), Swastika (1969, 1970), Dryden (1971, 1972, 1976), Thunder Bay (1971, 1972, 1976, 1977), Kirkwood

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15 Gross, H.L. 1979. Great Lakes Forest Research Centre, Sault Ste. Marie, Ont. (unpubl. rep.).

16 Fung, M. 1979. Ont. Min. Nat. Resour., Orono, Ont. (unpubl. rep.).

(1976), and St. Williams (1974). Doubtless much damage has gone unrecorded over the years. The percentage of seedlings culled because of poor form ranges as high as 65% and commonly reaches the 40-50% level.

Studies carried out in 1978 at Midhurst, Thunder Bay and Swastika nurseries by Gross (1983; see also footnote 15) indicate that ML in 1+0 white spruce is less than 2%. However, in 2+0 spruce this increases to approximately 20% depending on the nursery. During 1980, 1981 and 1982, Professors Hofstra and Lumis of the University of Guelph conducted surveys of Ontario nurseries to determine the extent of ML. Two assessments were made each season, one in April before flushing to determine the number of malformed buds and one in July to determine the number of resultant multiple leaders. The sampling was carried out in white spruce and black spruce *(Picea mariana* [Mill.] B.S.P.) seedbeds. In each block of stock to be assessed, three counts were taken, the rows and the location within the row being randomly selected. In 1980 a fixed plot area was counted and assessed directly in the field. In 1981 and 1982 only the first 100 seedlings in each plot were sampled.

Table 1 summarizes the incidence of ML for the years 1980, 1981 and 1982. The data indicate that the degree of damage varies from year to year (white spruce 2+0 Midhurst, 1980 - 18%, 1981 - 21%, 1982 - 31%) and from nursery to nursery. There is an indication that the amount of ML generally increases from the 2+0 to 3+0 year, particularly for white spruce.

EFFECTS OF MULTIPLE LEADERING ON EARLY OUTPLANTING PERFORMANCE

To determine the effect of ML on tree form in plantations, two outplanting tests were undertaken, one by Dr. H.L. Gross of the Great Lakes Forest Research Centre and one by Professors Hofstra and Lumis.

The first experiment by Dr. Gross consisted of seven tests located in three locations (Table 2). Plantings were done in June 1978 and remeasurements were done annually for three growing seasons. Bundles of test seedlings were randomly selected from normal shipping stock. Plots were selected after planting. The data represent the distribution of ML resulting from operationally culled nursery stock. Swastika and Thunder Bay planting sites were located in forest areas. The Midhurst site was in a cultivated field.

Table 2 contains the data from this experiment. After standard operational culling, 13-61% of the seedlings had ML. There was no apparent difference in survival between SL and ML seedlings. It appeared that as many SL trees became ML as ML trees became SL. Growth performance data are still being analyzed but it appears that the height growth of seedlings that have passed through the normal culling operation is similar for SL and ML. However, seedlings that remained ML throughout the test period did not grow in height as well as those that remained SL. There is a suggestion that ML seedlings that meet the size standards when they have been graded perform as well with respect to height growth and may in fact exhibit more growth than SL seedlings. Data on seedling size at planting time indicate that ML seedlings had more mass or dry weight.

Table 1. Incidence of multileadering (%) at provincial nurseries in July 1980, 1981 and 1982.

Species	Age	Year	Kemptville	Midhurst	Orono	St. Williams	Thessalon	Chapleau	Swastika	Thunder Bay	Dryden
White spruce	2+0	80	7	18	3	1	-	-	14	4	-
		81	12	21	8	10	-	19	23	11	-
		82	25	31	7	4	-	-	10	22	31
White spruce	3+0	80	0	4	1	3	2	-	-	5	-
		81	29	33	42	19	-	-	-	20	-
		82	25	27	29	27	-	-	-	0	-
Black spruce	2+0	80	-	4	-	-	1	9	14	1	-
		81	7	16	-	-	37	-	12	6	-
		82	-	-	-	-	-	-	5	6	41
Black spruce	3+0	80	-	-	-	-	-	10	-	-	-
		81	-	-	-	-	-	34	-	-	-
		82	-	-	-	-	-	-	-	-	-

Table 2. Performance of seedlings planted in 1978 and assessed in 1980 after three growing seasons.

		Midhurst White spruce $1\frac{1}{2}+1\frac{1}{2}$ (%)	Swastika White spruce $1\frac{1}{2}+1\frac{1}{2}$ (%)	Thunder Bay White spruce $1\frac{1}{2}+1\frac{1}{2}$ (%)	Swastika Black spruce $1\frac{1}{2}+1\frac{1}{2}$ (%)	Thunder Bay Black spruce 3+0 (%)	Midhurst White pine $1\frac{1}{2}+1\frac{1}{2}$ (%)	Swastika Jack pine 2+0 (%)
a)	No. of ML seedlings at planting time	61.0	49.0	30.8	44.5	35.2	13.0	39.0
	Change in status at least once after three seasons							
b)	SL to ML	74.6	70.4	64.2	62.8	42.0	48.5	40.5
	ML to SL	61.5	69.4	38.2	67.4	68.5	92.3	93.5
	Average	69.5	69.9	56.4	64.3	47.9	54.4	61.1
	Percentage of mortality after three seasons							
c)	SL (%)	0.0	3.9	4.4	15.3	18.4	4.0	0.8
	ML (%)	0.0	0.0	9.8	48.3	14.5	0.0	1.3
	Average	0.0	2.0	6.1	30.0	17.0	3.5	1.0

The second outplanting experiment was undertaken by Professors Hofstra and Lumis. Seedlings for this experiment were selected from stock that had been graded for shipping. This stock was then resorted so that 200 seedlings were single-leadered, 200 were double-leadered and 200 had more than two leaders. These were outplanted in a former nursery field at Midhurst by nursery staff in May 1981. No postplanting weed control was undertaken. After two growing seasons 10% of the SL seedlings became ML and 26-39% of the ML became SL (Table 3). This test suggests a trend towards SL trees and increased apical dominance when no winter injury or insect damage affects the terminal. Assessments over the next few years are required to confirm this observation.

Table 3. Performance of white spruce 3+0 outplanted stock after two growing seasons.

	Change in leader status (%)		
	200 singles	200 doubles	200 multiples
SL to ML	10%	-	-
ML to SL	-	39%	26%

RECOMMENDATIONS FOR FUTURE RESEARCH

1. To continue the survey of Ontario nurseries for the presence of ML to provide base data and yearly trends in occurrence.

2. To assess the amount of cull, at time of transplanting and shipping of nursery stock, resulting from the presence of ML, and to determine its impact on nursery production.

3a. To focus further research efforts on seedling hardiness in relation to ML occurrence. This study should be run concurrently with physiological assessment of plant hardiness in relation to ML.

   1) To develop a cultural regime to minimize ML occurrence through modified cultural practice such as nitrogen fertilization, and other techniques (wrenching, shading, growth regulating chemicals, etc.) that affect seedling shoot growth, bud development and frost hardiness. This study should be run concurrently with physiological assessment of plant hardiness, shoot growth and bud and needle development.

2) To develop modified irrigation methods for frost protection of bare-root conifer stock in early fall and late spring for northern Ontario nurseries.

3b. To focus further research efforts on effects of herbicides and interaction with other factors associated with ML.

1) Herbicide testing should include residue analysis in non-target crop species and soil in conjunction with effects on seedling morphology throughout the crop rotation and should include assessment of bud abnormalities and ML.

2) The role of herbicides and other associated factors such as weather, high nitrogen status, micronutrient deficiency, etc., in bud formation, lesion development and shoot growth and form needs further in-depth study.

3c. To focus further research efforts on effects of ML on plantation development.

1) To maintain data acquisition for the existing studies examining the effects of ML on plantation development to at least year 10 in order to confirm current trends.

2) To establish semioperational plantings to examine further the effects of ML on plantation development.

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